Imaging and Mapping of Quantum-Like Behavior in a Hydrodynamic System

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Abstract

A pilot-wave hydrodynamic system consists of a small droplet of silicone oil that is self-propelled across a vibrating bath of the same liquid. Bouncing vertical motion and "walking" horizontal motion of the droplet can be achieved with careful control over the frequency and amplitude of the oil bath oscillations. The observed "walking" motion is due to the interaction of the droplet with the waves that it generates as it bounces off of the vibrating liquid surface. This system provides a compelling macroscopic analog to the Bohmian pilot-wave interpretation of quantum mechanics. We present results from our hydrodynamic system, including efforts to observe single-particle interference, diffraction, and wave-guide behavior.

References


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Standing Waves at High Amplitudes

Within a narrow range of amplitudes for a given frequency, the self-propelled droplets (“walkers”) wander across a completely flat oil surface. The droplet motion is governed entirely by the waves that the droplet itself creates. For short time scales, the motion exhibits apparently random behavior (below), but for longer times, interference patterns emerge that are completely different from the standing wave patterns generated at higher oscillation amplitudes. These patterns are due to the interference of the droplet with itself! This behavior is analogous to a single electron trapped in a “quantum corral.” The beginnings of a central peak within a narrow range of amplitudes for a given frequency, the self-propelled droplets (“walkers”) wander across a completely flat oil surface. The droplet motion is governed entirely by the waves that the droplet itself creates. For short time scales, the motion exhibits apparently random behavior (below), but for longer times, interference patterns emerge that are completely different from the standing wave patterns generated at higher oscillation amplitudes. These patterns are due to the interference of the droplet with itself! This behavior is analogous to a single electron trapped in a “quantum corral.”

Intermediate Regime

As the oscillation amplitude is reduced, the bright of the surface waves inside the oil bath will decrease until they are barely visible (above). As a result, the waves generated by the droplet bouncing on the oil surface will have a greater impact over its subsequent motion. The patterns generated by the motion of the droplet (below) evolve significantly over time, showing evidence of the self-propelled (nonstationary randomized) droplet motion as well as the influence of the (highly structured) standing waves.

Free-Particle Trajectories

Within a narrow range of amplitudes for a given frequency, the self-propelled droplets (“walkers”) wander across a completely flat oil surface. The droplet motion is governed entirely by the waves that the droplet itself creates. For short time scales, the motion exhibits apparently random behavior (below), but for longer times, interference patterns emerge that are completely different from the standing wave patterns generated at higher oscillation amplitudes. These patterns are due to the interference of the droplet with itself! This behavior is analogous to a single electron trapped in a “quantum corral.”

Diffraction & Wave Guides

Within a narrow range of amplitudes for a given frequency, the self-propelled droplets (“walkers”) wander across a completely flat oil surface. The droplet motion is governed entirely by the waves that the droplet itself creates. For short time scales, the motion exhibits apparently random behavior (below), but for longer times, interference patterns emerge that are completely different from the standing wave patterns generated at higher oscillation amplitudes. These patterns are due to the interference of the droplet with itself! This behavior is analogous to a single electron trapped in a “quantum corral.”

Commercial Shaker System

A six-inch diameter dish was affixed to a steel backing plate and mounted to a commercial permanent magnet shaker (Data Physics Signal Force GW-V20). The large bath area allows for excellent free-particle motion, and will be used to test pilot-wave dynamics. Magnets can be affixed to the dish just below the oil surface to create various diffraction, interference, and wave-guide geometries.

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